Appendix F

BACT Cost-Effectiveness Data

Energy Corporation

Cost Analysis of NO_x Control Alternatives for Stationary Gas Turbines

Contract No. DE-FC02-97CHIO877

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TABLE A-5
1999 CONVENTIONAL SCR COST COMPARISON

				5 MW Class	25 MW Class	150 MW Class
Turbine Model				Solar Centaur 50	GE LM2500	GE Frame 7FA
Turbine Output				4.2 MW	23 MW	161 MW
Direct Capital Costs (DC):			Source			
Purchased Equip. Cost (PE):			MHIA			
Basic Equipment (A):			MHIA	$240,000	$660,000	$2,100,000
Ammonia injection skid and storage	0.00 x A		MHIA	included	included	included
Instrumentation	0.00 x A		OAQPS	included	included	included
Taxes and freight:	0.08 A x B		OAQPS	$19,015	$52,746	$169,530
PE Total:				$256,704	$712,066	$2,288,649
Direct Installation Costs (DI):*						
Foundation & supports:	0.08 x PE		OAQPS	$20,536	$56,965	$183,092
Handling and erection:	0.14 x PE		OAQPS	$35,939	$99,689	$320,411
Electrical:	0.04 x PE		OAQPS	$10,268	$28,483	$91,546
Piping:	0.02 x PE		OAQPS	$5,134	$14,241	$45,773
Insulation:	0.01 x PE		OAQPS	$2,567	$7,121	$22,886
Painting:	0.01 x PE		OAQPS	$2,567	$7,121	$22,886
DI Total:				$77,011	$213,620	$686,595
DC Total:				$333,716	$925,686	$2,975,244
Indirect Costs (IC):						
Engineering:	0.10 x PE		OAQPS	$25,670	$71,207	$100,000
Construction and field expenses:	0.05 x PE		OAQPS	$12,835	$35,603	$114,432
Contractor fees:	0.10 x PE		OAQPS	$25,670	$71,207	$228,865
Start-up:	0.02 x PE		OAQPS	$5,134	$14,241	$45,773
Performance testing:	0.01 x PE		OAQPS	$2,567	$7,121	$22,886
Contingencies:	0.03 x PE		OAQPS	$7,701	$21,362	$68,659
IC Total:				$79,578	$220,741	$580,616
Total Capital Investment (TCI) = DC + IC):				$413,294	$1,146,427	$3,555,861
Direct Annual Costs (DAC):						
Operating Costs (O):	24 hrs/day, 7 days/week, 50 weeks/yr					
Operator:	0.5 hr/shift	25 $/hr for operator pay	OAQPS	$13,125	$13,125	$13,125
Supervisor:	15% of operator		OAQPS	$1,969	$1,969	$1,969
Maintenance Costs (M):						
Labor:	0.5 hr/shift	25 $/hr for labor pay	OAQPS	$13,125	$13,125	$13,125
Material:	100% of labor cost		OAQPS	$13,125	$13,125	$13,125
Utility Costs:	0% thermal eff	600 (F) operating temp				
Gas usage	0.0 (MMcf/yr)	1,000 (Btu/ft3) heat value				
Gas cost	3,000 ($/MMcf)		variable			
Perf. loss:	0.5%					
Electricity cost	0.06 ($/kwh) performance loss cost penalty		variable	$10,584	$57,960	$405,720
Catalyst replace:	assume 30 ft^3 catalyst per MW, $400/ft^3, 7 yr. life		MHIA	$10,352	$56,690	$396,833
Catalyst dispose:	$15/ft^3*30 ft^3/MW*MW*.2054 (7 yr amortized)		OAQPS	$388	$2,126	$14,881
Ammonia:	360 ($/ton) [tons NH_3 = tons NO_x * (17/46)]		variable	$3,510	$14,820	$108,257
NH_3 inject skid:	5 (kW) blower	5 kw (NH_3/H_2O pump)	MHIA	$5,040	$7,560	$27,720
Total DAC:				$71,219	$180,500	$994,755
Indirect Annual Costs (IAC):						
Overhead:	60% of O&M		OAQPS	$24,806	$24,806	$24,806
Administrative:	0.02 x TCI		OAQPS	$8,266	$22,929	$71,117
Insurance:	0.01 x TCI		OAQPS	$4,133	$11,464	$35,559
Property tax:	0.01 x TCI		OAQPS	$4,133	$11,464	$35,559
Capital recovery:	10% interest rate,	15 yrs - period				
	0.13 x TCI		OAQPS	$52,976	$143,272	$415,329
Total IAC:				$94,314	$213,935	$582,370
Total Annual Cost (DAC + IAC):				$165,533	$394,435	$1,577,125
NO_x Emission Rate (tons/yr) at 42 ppm:				33.4	141.0	1030.0
NO_x Removed (tons/yr) at 9 ppm.	79% removal efficiency			26.4	111.4	813.7
Cost Effectiveness ($/ton):				$6,274	$3,541	$1,938
Electricity Cost Impact (¢/kwh):				0.469	0.204	0.117

*Assume modular SCR is inserted into existing HRSG spool piece

TABLE A-7
1999 SCONOX COST COMPARISON

		Source	5 MW Class	25 MW Class	150 MW Class
Turbine Model			Solar Centaur 50	GE LM2500	GE Frame 7FA
Turbine Output			4.2 MW	23 MW	170 MW
Direct Capital Costs (DC):		Source			
Purchased Equip. Cost (PE):		Goalline			
Basic Equipment (A):		Goalline	$620,000	$1,960,000	$7,700,000
Ammonia injection skid and storage	0.00 x A	Goalline	included	included	included
Instrumentation	0.00 x A	OAQPS	included	included	included
Taxes and freight:	0.08 A x B	OAQPS	$49,760	$157,105	$612,238
PE Total:			$671,760	$2,120,916	$8,265,208
Direct Installation Costs (DI):*					
Foundation & supports:	0.08 x PE	OAQPS	$53,741	$169,673	$661,217
Handling and erection:	0.14 x PE	OAQPS	$94,046	$296,928	$1,157,129
Electrical:	0.04 x PE	OAQPS	$26,870	$84,837	$330,608
Piping:	0.02 x PE	OAQPS	$13,435	$42,418	$165,304
Insulation:	0.01 x PE	OAQPS	$6,718	$21,209	$82,652
Painting:	0.01 x PE	OAQPS	$6,718	$21,209	$82,652
DI Total:			$201,528	$636,275	$2,479,562
DC Total:			$873,288	$2,757,191	$10,744,770
Indirect Costs (IC):					
Engineering:	0.10 x PE	OAQPS	$67,176	$212,092	$826,521
Construction and field expenses:	0.05 x PE	OAQPS	$33,588	$106,046	$413,260
Contractor fees:	0.10 x PE	OAQPS	$67,176	$212,092	$826,521
Start-up:	0.02 x PE	OAQPS	$13,435	$42,418	$165,304
Performance testing:	0.01 x PE	OAQPS	$6,718	$21,209	$82,652
Contingencies:	0.03 x PE	OAQPS	$20,153	$63,627	$247,956
IC Total:			$208,246	$657,484	$2,562,214
Total Capital Investment (TCI = DC + IC):			$1,081,534	$3,414,675	$13,306,985
Direct Annual Costs (DAC):					
Operating Costs (O):	24 hrs/day, 7 days/week, 50 weeks/yr				
Operator:	0.5 hr/shift; 25 $/hr for operator pay	OAQPS	$13,125	$13,125	$13,125
Supervisor:	15% of operator	OAQPS	$1,969	$1,969	$1,969
Maintenance Costs (M):					
Labor:	0.5 hr/shift; 25 $/hr for labor pay	OAQPS	$13,125	$13,125	$13,125
Material:	100% of labor cost	OAQPS	$13,125	$13,125	$13,125
Utility Costs:					
Perf. loss:	0.5%				
Electricity cost	0.06 ($/kwh) performance loss cost penalty	variable	$10,584	$57,960	$428,400
Catalyst replace	** kcfh/MW		$25,880	$106,295	$785,855
Catalyst dispose	precious metal recovery = 1/3 replace cost	variable	-$8,618	-$35,396	-$261,623
H2 carrier steam	*** lb/hr (93 lb/hr steam/MW @$.006/lb)	variable	$19,686	$107,806	$796,824
H2 reforming	**** CH4 ft3/hr (14ft3/hr/MW @ $.00388/ft3)	variable	$1,916	$10,495	$77,569
H2 skid demand	***** kW (0.6 kW/MW capacity)		$1,270	$6,955	$51,408
Total DAC:			$92,063	$295,458	$1,919,577
Indirect Annual Costs (IAC):					
Overhead:	60% of O&M	OAQPS	$24,806	$24,806	$24,806
Administrative:	0.02 x TCI	OAQPS	$21,631	$68,293	$266,140
Insurance:	0.01 x TCI	OAQPS	$10,815	$34,147	$133,070
Property tax:	0.01 x TCI	OAQPS	$10,815	$34,147	$133,070
Capital recovery:	10% interest rate; 15 yrs - period; 0.13 x TCI	OAQPS	$138,791	$434,965	$1,646,226
Total IAC:			$206,858	$596,358	$2,203,312
Total Annual Cost (DAC + IAC):			$298,921	$891,816	$4,122,889
NO_x Emission Rate (tons/yr) at 25 ppm:			19.9	83.9	645.9
NO_x Removed (tons/yr) at 2 ppm.	92% removal efficiency		18.3	77.2	594.2
Cost Effectiveness ($/ton):			**$16,327**	**$11,554**	**$6,938**
Electricity Cost Impact (¢/kwh):			**0.847**	**0.462**	**0.289**

* Assume modular SCONOx unit is inserted downstream of HRSG

** 400, 300, 300 kcfh/MW for 5, 25, 150 MW class respectively (s.v.=20kcfh/ft3, $1,500/ft3 catalyst, 7 yr. life)

*** 391, 2139, 15810 lb/hr for 5, 25, 150 MW class respectively

**** 59, 322, 2380 CH4ft3/hr for 5, 25, 150 MW class respectively

***** 3, 14, 102 kW for 5, 25, 150 MW class respectively

REVISED
BEST AVAILABLE CONTROL TECHNOLOGY ANALYSIS

TOWANTIC ENERGY PROJECT

FEBRUARY 2000

R·W·BECK

1998). This value is derived by a formula specified by CTDEP. The Project's maximum emission rate will be 10 ppm, or 43 percent of the allowable MASC limit.

The use of an SCR for NO_x control in combination with an oxidation catalyst for control of CO may increase particulate emissions in the form of ammonium bi-sulfates. Due to the insignificant amount of sulfur in natural gas fuel this impact will be extremely small. During oil-fired operation (the Project will be limited to 720 hours per year of oil-fired operation) the estimated amount of ammonium bi-sulfate emissions will increase particulate emissions by approximately 60 pounds per hour. This increase has only a minor effect on the maximum predicted air quality impacts from the Project, which are well within National Ambient Air Quality Standards.

An environmental benefit of SCR, when combined with a CO Oxidation Catalyst (Section 1.3), is a decrease in emissions of VOCs. Although the Project is not required to include VOCs in the PSD review as discussed in Section 1.1, the use of an SCR and CO Oxidation Catalyst will ensure that VOC emissions are minimal. The reduction in VOC emissions from SCR/CO Oxidation Catalyst is comparable to that from $SCONO_x$™.

ENERGY ANALYSIS

Use of SCR for NO_x control has an energy penalty due to the energy required to force combustion gases through the SCR reactor. There are other energy requirements associated with chemical transport and operation of equipment, pumps and motors but these are relatively small. Operation of the SCR for the Towantic Project is estimated to reduce electrical output by 1.46 MW or 11,510 MWh of electricity per year[1]. Not only is the electrical output reduced but the fuel use is increased by 135,800 MCF of gas per year.

1.2.4.1.3 ECONOMIC ANALYSIS

Table 3 presents the capital and annualized cost for the SCR control option downstream of a DLN combustor. The costs are itemized to include capital cost of equipment and operation costs for personnel, maintenance, replacement parts (primarily catalyst), energy penalties and ammonia. All costs are for two GE Frame 7FA gas turbine units, each including one HRSG, which includes the SCR unit.

[1] Based on annual capacity factor of 90%.

issues, poses a serious concern as to whether the Project could secure final construction approval from the Council.

As with the SCR/CO Oxidation Catalyst, $SCONO_x$™ will reduce VOC emissions along with NO_x and CO. The Project is not required to include VOCs in the PSD review, as discussed in Section 1.1, however, $SCONO_x$™ does have the added benefit of decreasing VOC emissions. The reduction in VOC emissions from $SCONO_x$™ is comparable to that from SCR/CO Oxidation Catalyst.

1.2.4.2 .2 ENERGY ANALYSIS

Use of $SCONO_x$™ for NO_x control has an energy penalty due to the energy required to force combustion gases through the $SCONO_x$™ reactor (pressure drop). Pressure drop through the $SCONO_x$™ unit is estimated at 5.25 inches by the manufacturer. This is compared to approximately 3.5 inches of pressure drop for a combined SCR and CO catalyst installed in a HRSG. The pressure drop of 5.25 inches reduces the total plant output by approximately 2.19 MW or 17,266 MWh per year. Not only is the electrical output reduced but the fuel use is increased by 202,200 MCF of gas per year.

Production of the steam used in the regeneration process also imposes a penalty in that the steam is not available to generate electricity. Based on the manufacturer's estimate of low-pressure steam requirements of 15,000 pounds per hour at 600°F and 20 psig, the steam turbine capability of the Project will be reduced by approximately 2.5 MW or 19,710 MWh per year.

The additional energy requirements of the $SCONO_x$™ system (relative to other NO_x control technology) means that the incremental amount of energy will not be supplied by the Project to meet energy needs in the service area. Other power plants will make-up the difference (approximately 4.2 MW) and this will result in a proportional increase in air pollution emissions. These other power plants may emit at levels equal to or greater than the Project.

As with any mechanical system, there are energy requirements associated with the operation of equipment, pumps and motors but these are relatively small. Finally, the $SCONO_x$™ system consumes 200 pounds per hour of natural gas total for regeneration of the catalyst plus leakage. This results in an annual natural gas consumption of 41,800 MCF.

1.2.4.2.3 ECONOMIC ANALYSIS

Table 4 presents the capital and annualized cost for the $SCONO_x$™ control option downstream of a DLN combustor. The costs are itemized to include capital cost of equipment and operation costs for personnel, maintenance, replacement parts (primarily catalyst) and energy costs. These costs are based on general information provided during a meeting with representatives from ABB Environmental. ABB Environmental was not able to provide a specific cost quote for a $SCONO_x$™ system for a GE 7FA combustion turbine with a HRSG. The projected capital costs are based on a $SCONO_x$™ system designed for an ABB GT-24 unit adjusted for the GE 7FA. The $SCONO_x$™ system also reduces